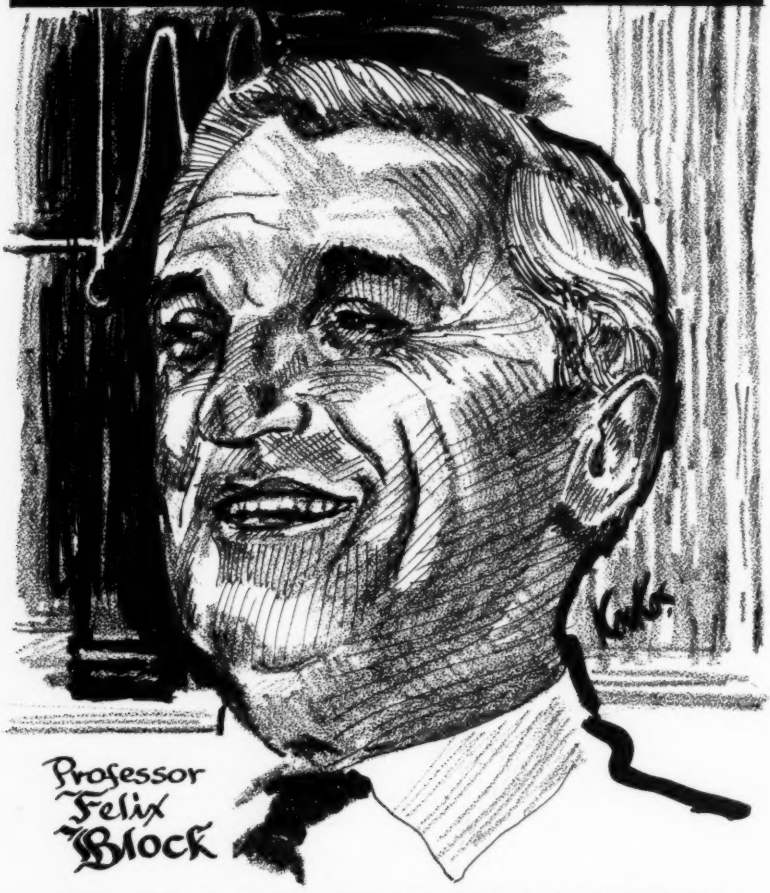
NAVAL RESEARCH

REVIEWS

MARCH 1970

Portraits in Science



AFTER GRADUATE WORK AT THE UNIVERSITY OF LEIPZIG, DR. BLOCH JOINED THE FACULTY OF STANFORD IN 1934 WHERE HE IS PHYSICS PROFESSOR TODAY. HIS CAREER AT STANFORD WAS INTERRUPTED DURING WORLD WAR II WHEN HE WORKED FOR THE MANHATTAN PROJECT AND THE RADIO RESEARCH LABORATORY AT HARVARD. DR. BLOCH, WHO IS ONE OF THE WORLD'S LEADING THEORETICIANS IN SOLID STATE PHYSICS, DISCOVERED A METHOD OF STUDYING THE MAGNETISM OF ATOMIC NUCLEI IN NORMAL MATTER, WHICH PERMITS VERY HIGH PRECISION MEASUREMENTS (NUCLEAR MAGNETIC RESONANCE). INDEPENDENTLY AND SIMULTANEOUSLY THE SAME DISCOVERY WAS MADE BY E. M. PURCELL, WITH WHOM BLOCH SHARED THE NOBEL PRIZE FOR PHYSICS IN 1952. IN 1954 DR. BLOCH BECAME THE FIRST DIRECTOR OF CERN (EUROPEAN LABORATORY FOR NUCLEAR RESEARCH AT GENEVA). FOR MANY YEARS DR. BLOCH HAS BEEN ONE OF ONR'S MAJOR RESEARCHERS.

XUM

Amorphous Semiconductors

Robert G. Morris
Office of Naval Research
Washington, D.C.

What is an amorphous semiconductor?

Amorphous means noncrystalline, or irregular in internal structure. A semiconductor is a material that has a smaller electrical resistance at higher temperatures than at lower temperatures. In metals the effect is opposite. Examples of amorphous semiconductors include germanium, silicon, selenium and mixtures of these.

Are transistors and diodes in present solid state systems made of amorphous semiconductors?

No. The germanium, silicon and other materials used in radios, TV's and computers are in crystalline form. In crystals the atoms are arranged in repeated patterns, as indicated in Figure 1. A diagram of an amorphous arrangement of the same type of atoms is also shown in Figure 1. Although the pattern is irregular, energy minimization requires that most atoms in the amorphous arrangement have the same number of bonds or connections to nearest neighbors as in the crystalline arrangement.

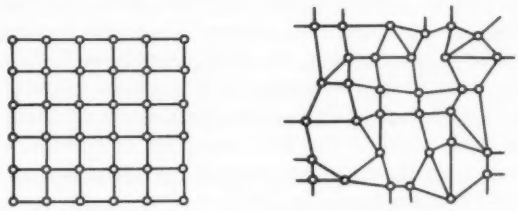


Figure 1 — In crystalline materials, left, atoms represented by circles are arranged in repeated patterns. In this case the pattern is a square. For the same type of atom in an amorphous arrangement, right, there is no repeated pattern. Nevertheless, most atoms are believed to have the same number of bonds (represented here by lines) with nearest neighbors as they do in the crystal.

Are amorphous materials generally harder to come by, harder to work with and harder to understand?

They are not particularly rare: glass, butter, rubber and plastics are examples of amorphous materials. Metals are usually crystalline, although the crystal unit in which the basic pattern is repeated perfectly

XUM

may be quite small. Elements like silicon, germanium and selenium, already mentioned, may occur with either an amorphous or a crystalline arrangement. The repeated pattern in crystals makes their mathematical analysis much easier than the more random arrangement in amorphous solids. Largely for this reason, crystalline semiconductors have been more widely prepared and studied. Consequently, solid state devices today are largely crystalline.

How have amorphous semiconductors been in the news lately?

Scientific periodicals, the *Wall Street Journal* and *Life* have all reported pioneering work on amorphous semiconductor devices by Mr. Stanford R. Ovshinsky at his small company in Troy, Michigan. A heavily-attended conference on amorphous solids sponsored by the Army's Picatinny Arsenal took place in New York in May 1969 and an international conference on the subject was held at Cambridge University in September 1969.

Why is there suddenly so much interest in amorphous semiconductors?

Mr. Ovshinsky has been represented in the press as a self-made man doggedly promoting an idea in the face of scientific and industrial opposition. This has attracted the attention of the general public. The same publicity has attracted outstanding scientists to the field to make their own contributions.

Where is amorphous semiconductor research being performed?

At Ovshinsky's company, of course, where he has assembled an impressive group of workers; at Bell Telephone Laboratories and IBM in this country; and in groups at Cambridge, Prague, Leningrad and Bucharest in Europe. ONR is also sponsoring research in the field. Much of the early work in the field was done in Europe, as shown by the location of both the previous international meetings on the subject: Prague in 1965 and Bucharest in 1967.

Can useful devices be made from amorphous semiconductors?

Two have been widely discussed: the threshold switch and the memory switch.

What is a threshold switch?

Figure 2 shows the output current as a function of the applied voltage for a typical threshold switch element. The current builds up very slowly as the voltage is increased until the threshold voltage V_t is reached; then it jumps (dotted line) to a very large value in about 10^{-9} sec. In this condition, the switch is on. If the voltage is now reduced, the current falls along the top curve until a critical value of current I_t is reached; after this, it switches back to the low-current curve and

XUM

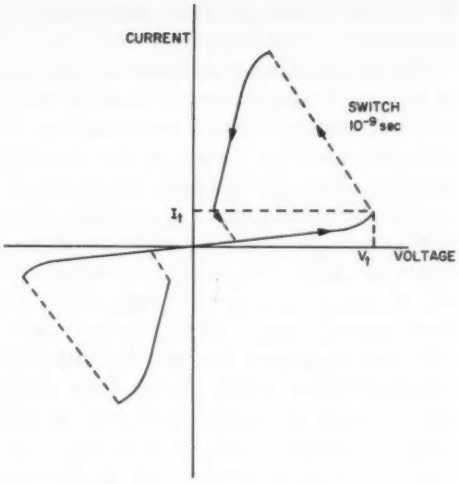


Figure 2 – Current through a switch as a function of the voltage across it. In a threshold switch the current jumps to a large value in about 10^{-9} sec (dotted line) when the voltage increases to the threshold value V_t. The switch is then on. When the voltage is reduced so that the current reaches I_t, it falls back to a value on the lower solid curve. The switch is then off. In the memory switch there is not threshold current I_t. Reduction of the voltage to zero does not turn the switch off, since reapplication of even a small voltage gives the larger current determined by the upper solid curve.

the switch is off. The ratio of resistance between the two modes of operation is about 1000:1.

What is a memory switch?

The memory switch made out of an amorphous semiconductor has the same current-voltage curve (Figure 2) as the threshold switch except for the absence of a critical current I_t. Once in the low-resistance mode, the switch remains in that mode even if the applied voltage is reduced to zero and the current flow ceases. Reapplication of voltage again gives the high current. It is returned to its high-resistance mode only by a reset voltage pulse which allows a large current to flow briefly.

Are these two-terminal components polarized in any way?

No. Both the threshold and the memory amorphous-semiconductor switches are unpolarized. This means they have symmetric constant-voltage curves (Figure 2) and operate in the same fashion regardless of the direction of current. This is an obvious advantage for certain types of alternating current operation.

How are the devices constructed?

A thin film of amorphous semiconductor, often a mixture of silicon, germanium, arsenic, tellurium and phosphorous, which is about 10 microns thick, is situated between two metallic electrodes.

What is meant by the term Ovonic?

Ovonic was coined to characterize threshold and memory switches produced by Mr. Ovshinsky's company.

XUM

What are some possible applications of amorphous-semiconductor switches?

The change in resistance (and in some materials, the optical reflectance) in memory switches seems a likely mechanism for computer components and information storage, providing fast access. Exposure to light may alter the threshold voltage so that a switch could be used as an optical detector. The structureless character of amorphous semiconductors makes them insensitive to radiation damage, suiting them for device applications in space or other environments where particle radiation fluxes are high. The threshold switches may be useful in providing fast, on-off control of arrays of light emitters in electroluminescent panels. Such panels would allow relatively flat, graphic, optical readout of information without the use of a cathode ray tube. Related amorphous semiconductors which change their electrical properties upon heating may be used in copying machines utilizing xerographic ideas. A laser-written message might be recorded on a drum of such material since heating causes its conductivity to decrease. Charged inks would adhere only to this part of the drum and print out the copy.

Are amorphous-semiconductor devices comparable to the transistor?

No. The transistor is a three-terminal device; two terminals provide an input and one of these plus the third provide a controlled output. Such control, resulting in amplification, regulation or oscillation, is not possible with a two-terminal device such as present amorphous-semiconductor components.

What advantages over conventional crystalline components do amorphous-semiconductor devices promise?

Amorphous semiconductors are easier to prepare, ohmic contacts are easier to apply, there is less effect of impurities, and radiation damage such as x-rays.

What disadvantages?

Since the theoretical understanding of amorphous materials is very incomplete, their properties cannot be predicted or controlled. So far, these devices have not been operable at temperatures much above room temperature. The reproducibility and reliability of operation of the components has not been as good as desired. And, finally, they are so far only useful as two-terminal devices, which severely limits their application.

How well is the operation of amorphous-semiconductor devices understood?

Rather well, considering the complexity of the problem. However, only a start has been made in matching our knowledge of crystalline

XUM

solids. The situation has been compared with our understanding of crystalline semiconductors 30 years ago, just eight years before the invention of the transistor.

What do we know?

Professor Morrel Cohen, an ONR contractor at the University of Chicago and a consultant to Ovshinsky's company, has formulated a model to clarify the electrical behavior of amorphous semiconductors. This model takes into account that the discrete allowed and forbidden bands of electron energies so useful in describing crystals are not applicable to amorphous materials because of the lack of spatial order. The discrete bands become fuzzy-edged, with the new possibility of having some charge carriers with energy in the 'old' forbidden energy gap. Electrons with these energies, however, are not very free to move, but due to some rather abstract quantum mechanical reasons are localized in the solid. Electrons move from one localized energy state to the next under the action of an electric field by the slow process of hopping. In a crystal, the energy states are continuous and the electron glides smoothly through the material under the action of a field. The main feature of Cohen's model, published in collaboration with H. Fritsche and S. R. Ovshinsky, is a mobility gap that describes the jump or gap in mobility between electrons in the localized states and those in continuous states.

What is a mobility gap?

A mobility gap is to an amorphous semiconductor what an energy gap is to a crystalline semiconductor. This idea is illustrated in Figure 3. The top diagram represents the allowed and forbidden energy levels in a crystalline semiconductor; in the energy gap the ordinate is zero—no states allowed. In such a semiconductor the valence band states are filled with electrons and the conduction band states are empty (at least at temperature absolute zero). Thus conduction is poor, but it increases with temperature as a Maxwellian tail of electrons extends into the conduction band. (In a metal, the conduction band is partly filled to start with.) In the second diagram we see that the energy band picture breaks down for an amorphous material (due to the breakdown of crystalline order) and that there is no proper gap anymore. However, the states with energy between E_v and E_c are localized; even though they are occupied, the electrons occupying them are still not very mobile, or responsive to an electric field. Cohen suggests the concept of a mobility gap rather than energy gap, as shown in the bottom diagram, to explain correctly the electrical conduction properties of electrons in these amorphous semiconductors: electrons in localized states between E_v and E_c have low mobility; those in continuous states above E_c or

XUM

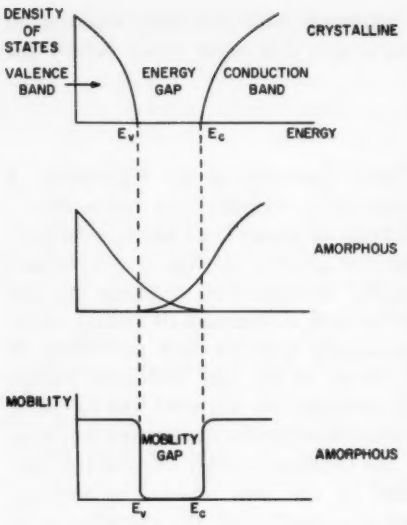


Figure 3 – Upper diagram: Density of electron energy states as a function of energy in a crystal. In a semiconductor the valence band is full and the conduction band is empty (at absolute zero). No electrons may have energies in the range marked Energy Gap. In a metal the conduction band is normally partly filled.
Center diagram: Density of electron energy states as a function of energy in an amorphous material. Electrons may now have energies in the energy gap, but these states are localized and the electrons are relatively immobile.
Bottom diagram: Electron mobility as a function of energy in an amorphous material. This is the substitution of a mobility gap in amorphous materials for the energy gap in crystals according to the Cohen model. Electrons in energy states between E_v and E_c have low mobility; electrons in other states can have high mobility.

below E_v may have high mobility. Thus there is a mobility gap or region of low mobility for energies between E_v and E_c.

What else is understood about the operation of amorphous-semiconductor devices?

The memory switch mechanism has been extensively studied and photographed. Some visible structural change takes place, usually in filaments which extend from one electrode to the other. The conductivity of this new structure is much lower. The filament may be wiped out by a high-voltage pulse. It has not yet been established whether this structural change is one of content or crystallinity, and whether it is caused thermally or electrically. The situation in the threshold switch is less well understood since the switching phenomenon takes place in about 10^{-9} sec and the device recovers for a new cycle in about 10^{-6} sec.

What problems remain in the understanding of amorphous semiconductors?

The Cohen model must be tested, the nature of the memory switch transition established, the mechanism of the threshold switch probed and the sorting of the conduction into that by hopping and gliding electrons carried out. Careful measurements at different laboratories on well-characterized samples will help bring order to some of the conflicting and fragmentary results reported up to now.

XUM

What is the most significant development in the field so far?

Probably the attraction of so many outstanding scientists to the field.

What course is future development likely to take?

No one really knows. It is likely that important applications of amorphous semiconductors will occur in places not yet thought of. It is normal that in a new field where the understanding of the phenomena is hazy, many applications can be imagined. As the understanding improves, the applications will be pin-pointed.

What interest has the Navy in amorphous semiconductors?

Naval ships, submarines, planes and personnel operate in a unique environment requiring the latest technological advances for communications, surveillance and navigation. Any application so far mentioned—like the flat electroluminescent display panel—or applications yet to come that would improve these fleet operations are of vital interest to the Navy.

Amorphous Semiconductor Glossary

amorphous	– without form, structureless, noncrystalline
semiconductor	– material whose electrical resistivity is high but decreases with increasing temperature
density of states	– available electron levels per unit energy
energy gap	– the separation between the highest filled energy band (valence band) and the lowest empty band (conduction band). Energies within the gap are forbidden.
mobility	– charge carrier velocity produced by unit electric field
threshold switch	– on-off switch that reverts to its off mode when the voltage is removed
memory switch	– on-off switch that, once switched, remains on even when the voltage is removed
monostable switch	– threshold switch
bistable switch	– memory switch
ohmic	– current directly proportional to voltage
localized state	– electronic energy state with restricted position
continuous state	– electron energy state with unrestricted position
mobility gap	– electron energy range where electron mobility is very small due to localized states

XUM

Melioidosis

Robert J. Heckly
Naval Biological Laboratory
Oakland, California

The Disease

In 1921 Stanton and Fletcher coined the term melioidosis for a bacterial disease that was first described as a disease in man by Whitmore and Krishnaswamy in 1912. The disease was feared because surveys suggested that 95 percent of the cases were fatal and little was known of the mode of transmission.

Melioidosis is difficult to diagnose because the symptoms are variable. The onset of illness is frequently characterized by headache, fever, chills, nausea, vomiting, diarrhea or chest pains, with or without a cough. Occasionally, melioidosis may resemble cholera and produce vomiting, diarrhea and collapse, with death following within three days, or it may produce a typhoid-like syndrome with fever and abscesses of the liver, spleen and kidney leading to death within 1-4 weeks. Slowly progressing or chronic cases frequently show discharges from bone sinuses or other deep lesions. This multiplicity of symptoms has led to misdiagnosis of melioidosis as: glanders, small pox, tuberculosis, plague, malaria, syphilis, amebic hepatitis, pneumonia, infective endocarditis, as well as typhoid and cholera.

Figure 1 shows the appearance of the liver, lung and spleen of a hamster 3 days after inhalation of approximately 46 melioidosis organisms. Three lesions were present in the lung, one of which is shown at the periphery. There was hemorrhagic pulmonary consolidation of the entire left lung and of portions of the right lung. The liver and kidneys were normal but many small lesions were present on the spleen. The Office of Naval Research and the Bureau of Medicine and Surgery have sponsored the experimental work conducted by the Naval Biological Laboratory on melioidosis. As a result of the work at NBL, we now have a modest understanding of this exotic disease.

The Organism

Diagnosis can be made only by bacteriological identification of the causative agent. The organism responsible for the disease had been classified once as *Malleomyces pseudomallei* because of similarities between melioidosis and glanders, caused by a bacterium then known as *Malleomyces mallei*. More recently it has been shown that melioidosis

XUM

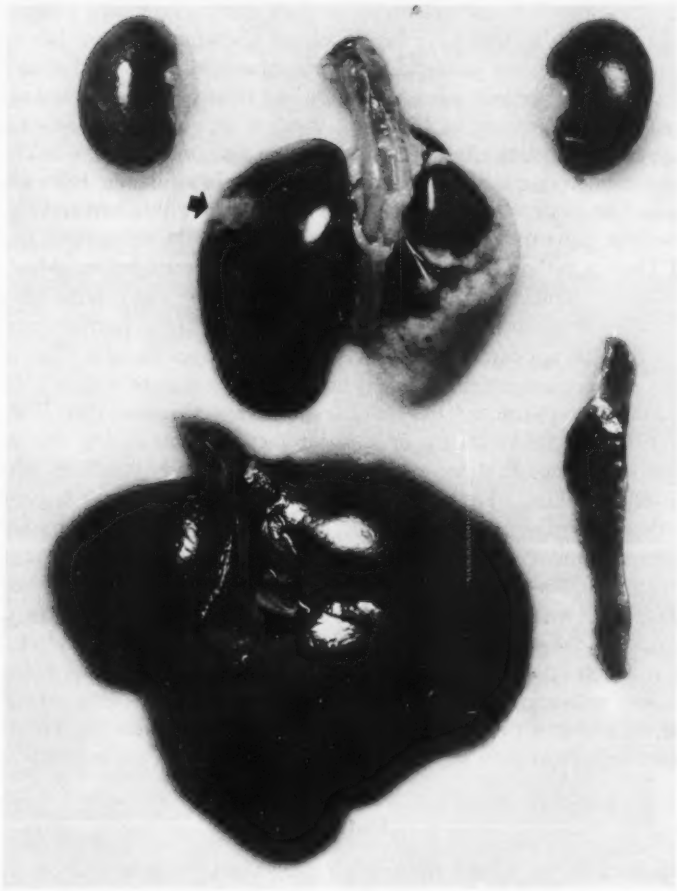


Figure 1 — Organs of hamster moribund 3 days after inhalation of approximately 46 organisms. Three lesions were present in the lungs, one of which is shown at the periphery of the left lung (arrow). There is hemorrhagic pulmonary consolidation of the entire left lung and of portions of the right lung. The spleen shows many small lesions. The liver and kidneys appear normal. From reference number 1.

organisms more closely resembled species of the genus *Pseudomonas*. Hence its name was changed to *Pseudomonas pseudomallei*. It is a small, gram negative, filamentous rod which generally exhibits bipolar staining. It requires oxygen for growth but it can survive for long periods without air. The color and appearance of colonies formed on agar are variable. Strains have been isolated that are cream, white,

379-054 O - 70 - 2

XUM

lavender, orange or brownish red. Figure 2 shows detailed morphology of selected strains that have been isolated and studied in our laboratory.

Unlike most other bacteria, the virulence or disease-producing properties of *Pseudomonas pseudomallei* is not related to its colonial appearance. As is illustrated in Figure 2, virulent strains may produce either rough or smooth colonies. However, within a strain there may be changes in appearance that are associated with changes in virulence. For example: Figure 3 shows colonies of strain 103 as it was first obtained and Figure 4 shows the same strain adapted to mice by many serial passages in this animal. Over a million cells were required to kill a mouse before it had been passaged, whereas 10 cells of the adapted strain was a lethal dose for mice. Figure 5 shows that the appearance of the strain partially reverted to its original appearance after only a few passages on agar. The rate of spontaneous change (mutation) is high, and this feature makes it difficult to study the characteristics of *Pseudomonas pseudomallei.* The high mutation rate undoubtedly is a major factor in producing the variety of colonial types that have been observed by many workers. Also the lack of correlation between virulence and colonial morphology, noted in other bacterial species, may be referrable to the high mutation rate of the pseudomallei group.

Pseudomonas pseudomallei grows well on organic media such as beef extract with 4 percent glycerin but it also grows well on simple chemically defined media. Ten billion cells per ml were easily obtained in a medium containing only ammonium gluconate, potassium phosphate and iron and magnesium sulfate. Thus it is far from being an obligate parasite and can easily survive in soil or water supplies. In this respect *Pseudomonas pseudomallei* resembles other pseudomonas types.

Distribution

Melioidosis is found throughout Southeast Asia with most of the cases being reported from Burma, Malay States and Viet Nam. In these areas, *Pseudomonas pseudomallei* is easily isolated from soil and surface water and from vegetables. Only a few cases have been reported from other areas of the world. The organism probably does not exist in the United States since only one case has been reported to have been completely indigenous to this country—all other American cases are believed to have been contracted outside of the United States.

Since 1965, 72 symptomatic cases of melioidosis were reported among United States troops in Viet Nam with 14 deaths—despite modern chemotherapy and medicine. Ten of the 72 cases developed only after the service men returned to the United States. In fact, there is one report which shows that illness developed 5 years after a soldier returned from Viet Nam. In this case, *Pseudomonas pseudomallei* acted like a biological time bomb.

XUM

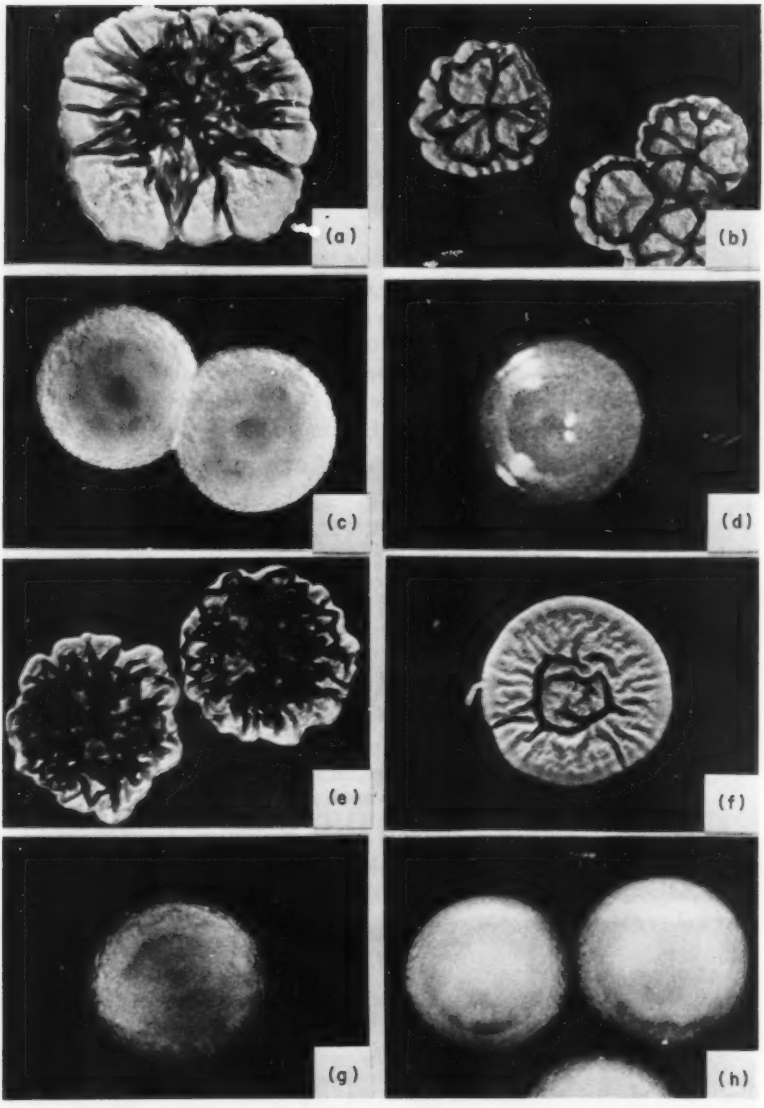


Figure 2 – Representative rough and smooth variants isolated from stock cultures of *Pseudomonas pseudomallei*. All strains were virulent since less than 100 cells were lethal for hamsters. All photographs at approximately 5.5X. (a) From strain 101. Rough yellow lacy type. (b) From strain 101. Rough white type. (c) From strain 101. Smooth white type. (d) From strain 104-2. Smooth yellow type. (e) From strain 102. Rough orange type. (f) From strain 102. Rough cream type. (g) From strain 103. Smooth cream type. (h) From strain 114. Smooth white type. (From reference number 2.)

XUM

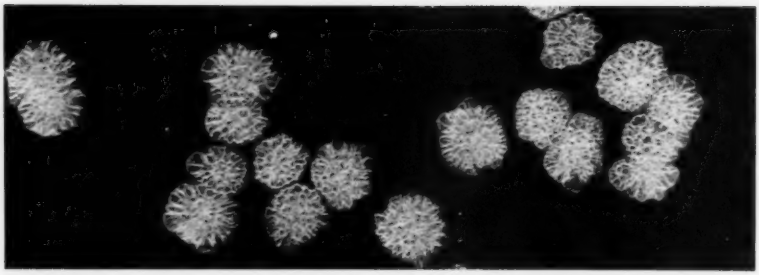


Figure 3 – Strain 103R before adaptation to mice. Large lacy rough yellow colonies.

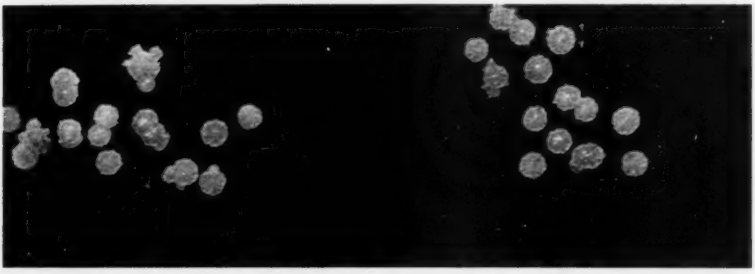


Figure 4 – Strain 103R after adaptation to mice, showing pure culture of small intermediate rough yellow colonies

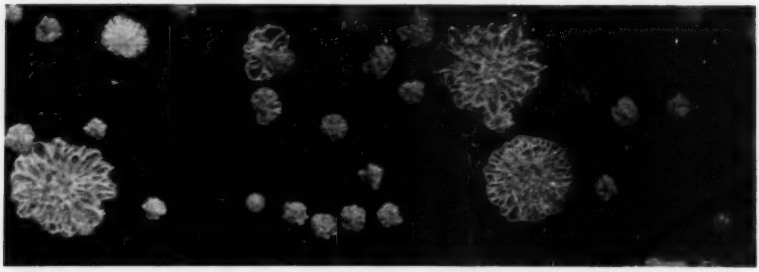


Figure 5 – Strain 103R, showing reversion to the parent type (in Figure 3) of the small intermediate rough yellow colony (in Figure 4) after several passages on agar. From reference number 2.

XUM

Epidemiology

Little is known of the epidemiology of melioidosis. Man-to-man transmission has never been demonstrated despite the lack of isolation procedures for infected persons in Southeast Asia. The most common "cause" of infection is an accident in which wounds become contaminated with mud.

Experimentally, we have shown that the disease can be transmitted to mice and hamsters by the respiratory route. Therefore this route cannot be excluded as a natural route of infection. Virulent strains produced focal necrosis in the lung whereas the avirulent strains did not when inhaled.

The organism was once thought to be endemic in the rodent population of Southeast Asia; however, a systematic study of thousands of rats resulted in the isolation of *Pseudomonas pseudomallei* from only one animal. Nevertheless, failure to find infected rats may be a reflection of the acute nature of the disease; infected animals may die in a matter of a few days and thus a sampling would not show rodents as a reservoir. Current evidence suggests, however, that this is not the case and it seems likely that the reservoir for the organism is, in fact, the soil.

In a serological study, Dr. Clara Nigg of the Naval Biological Laboratory, found that between 8 and 30 percent of the sera from over 300 adults in Thailand showed antibodies for *Pseudomonas pseudomallei.* She found that 8.3 percent of the Thai males gave positive complement fixation reactions for melioidosis. Since none of a comparable group in the United States showed such antibodies, the survey provides evidence that Thai people often experience exposure to *Pseudomonas pseudomallei* and that such exposure may produce subclinical or unrecognized mild melioidosis.

Approximately 30 percent of the adult Thai population reacted positively in the hemagglutination test, which also measures antibodies. This serological test is more sensitive, but probably less specific, than the complement fixation test since over 7 percent of the control group in the United States reacted positively. Recent studies show that the hemagglutination test can be made as specific as the complement fixation test by use of properly prepared antigens.

If the serologic reactions in humans disappeared gradually, as they do in experimental animals, the actual incidence of past infection (subclinical cases) in the endemic area may be even higher than indicated by the number of positive serological reactions at any one time of sampling. Thus it appears that the high mortality rate of 95 percent reported earlier is applicable only in those cases of melioidosis that are severe enough to require medical attention.

XUM

Chemotherapy

Despite an extensive search, no antibiotic has been found which is fully effective against all strains of *Pseudomonas pseudomallei*. Because of the great differences among various strains, sensitivity studies are important in the selection of the appropriate therapy. It was found that chlorotetracycline, but not the other tetracyclines, were effective against a number of strains. Most strains are resistant to colymycin, streptomycin, cephalosporin and ampicillin. Sulfadiazine, chloramphenicol, kanamycin, and novobiocin are reasonably effective. It is most important that therapy be continued for at least 15 days. Mice infected with *Pseudomonas pseudomallei* appeared to be cured after only 5 days of treatment, but as soon as therapy was discontinued may became ill again and died. The Armed Forces recommend 12 grams chloraphenicol, 4 grams kanamycin and 6 grams of novobiocin per day and that it be continued for 4 weeks.

Toxins

Early in our studies on the pathogenicity of *Pseudomonas pseudomallei*, we noted that frequently mice and hamsters which died within a few days after organisms were introduced intraperitoneally, showed no gross lesions. This observation suggested that the mice were killed by a toxin. Furthermore, we found that intraperitoneal or intravenous injection of sterile culture filtrates killed mice within 18 hours. Many of the animals, sick or dying after injection of the toxin, exhibited symptoms that were very similar to those observed in infected animals. Thus it appeared likely that one of the contributing causes of death in melioidosis was a toxin produced by the organisms during growth in the host. Although intravenous injection of culture filtrates produced no visible lesions, its injection intradermally produced severe hemorrhagic and necrotic lesions. Figure 6 shows the reaction of a guinea pig to intradermal injections of 0.1 ml of graded dilutions of culture filtrate. Within 5 minutes there was erythema and within 3 hours the hemorrhagic lesion was fully developed. By 24 hours the lesion was necrotic with considerable edema. As is indicated in this figure, the toxin was partially inactivated by heating to 60 C and completely inactivated by boiling.

Further study of the toxin of *Pseudomonas pseudomallei* showed that it was not only lethal and produced necrosis but it inhibited coagulation of plasma or blood and rapidly digested proteins.

The toxin could be purified by precipitation with alcohol or ammonium sulfate, or by chromatography. Since these procedures failed to separate the lethal and necrotizing toxins, it appeared that the basis of toxicity was the enzymatic activity. Furthermore, the lethal toxin and necrotizing

XUM

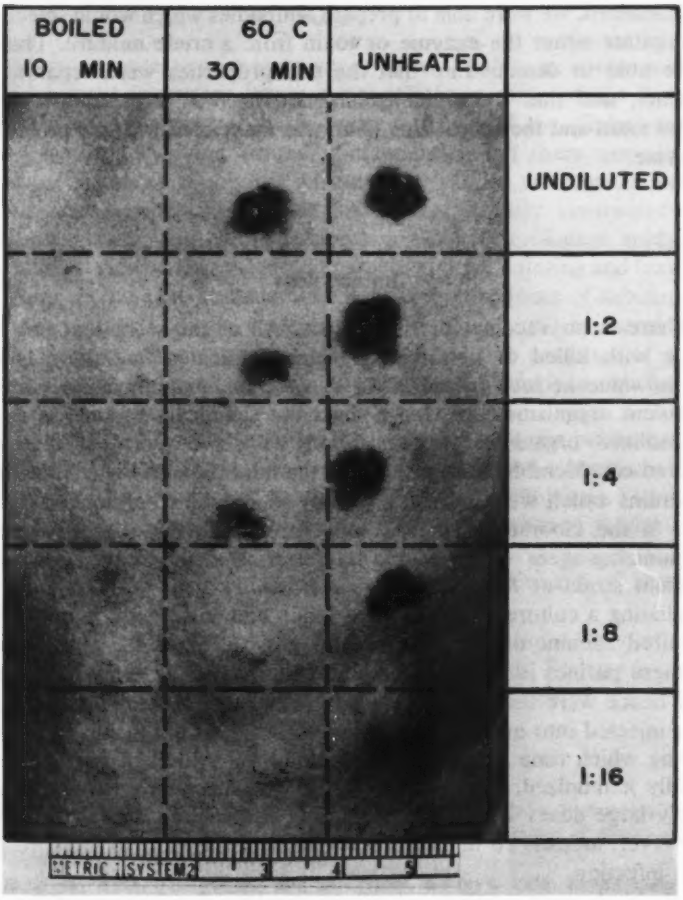


Figure 6 — Lesions in a guinea pig produced by intradermal inoculations of sterile filtrate from a 10-day-old broth culture of *Pseudomonas pseudomallei*, strain 111-9. The photograph was taken 4 hours after inoculation. From reference number 3.

toxin behaved in an identical manner in the ultracentrifuge and had the same electrical charge. However, the lack of lesions in mice killed by intravenous injection of the toxin indicated that the necrotoxin was not the cause of death. By comparing the effect of various treatments on the enzymatic activity and lethality, it was found that stability to acids and bases differed slightly. Following this lead, we found that by carefully adjusting the acidity of the toxic mixture, we could differentially inactivate one or the other material. Using these acid and alkali inactivated

XUM

preparations, we were able to prepare antibodies which would selectively precipitate either the enzyme or toxin from a crude mixture. Thus we were able to demonstrate that the two properties were separate and distinct, and that the anticoagulant activity was associated with the lethal toxin and the necrotizing toxin was associated with the proteolytic enzyme.

Immunology

There is no vaccine for melioidosis. All of the work that has been done with killed or non-living vaccines indicates that there is little or no value in such preparations as vaccines. Immunization with live avirulent organisms conferred a slight but significant protection against aerosolized organisms. Immunization with live avirulent organisms offered considerably more protection than did the non-living vaccines.

Strains which were avirulent, usually as a result of prolonged cultivation in the laboratory, offered some protection but a more effective immunizing agent was obtained by selecting a suitable mutant from a virulent strain of *Pseudomonas pseudomallei*. This was done by first irradiating a culture of the virulent strain and selecting a mutant which required adenine or hypoxanthine for growth. Since the concentration of these purines is low *in vivo*, the organisms did not reproduce rapidly and hence were essentially avirulent. When this purine requiring strain was injected into mice, the microorganisms persisted for up to 20 days, during which time antibodies were produced. Although mice were not solidly immunized, those receiving this vaccine were resistant to relatively large doses of virulent organisms administered intraperitoneally. However, animals so immunized remained susceptible to lethal respiratory infection.

Obviously such vaccines are not practical for man because of the great possibility of reversion to purine independence and virulence. However, if a double mutant were developed, the chances of mutation to a virulent strain would be quite remote.

As mentioned before, there is considerable evidence that infected mice are killed by a lethal toxin produced *in vivo* by the organisms. Thus attempts were made to immunize mice against the toxin. Immunization of mice with sublethal amounts of the toxic filtrate increased the resistance of mice by as much as 60-fold. This is not a high order of protection but, in view of the extremely small amount of toxin administered, it is significant. In these experiments the toxin *per se* was probably not solely responsible for the immunization since these culture filtrates also contained other soluble antigens which one might expect to be protective.

XUM

Future

A number of questions remain unanswered. Studies on epidemiology would be most important because we still know little of the factors associated with the spread of melioidosis. Many of the clinical cases have a history involving wound contamination but there are also a number of instances where it is difficult to determine the route of infection. In these instances, melioidosis was apparently contracted by inhalation, ingestion or through unbroken skin. A serological study of American servicemen, or other comparable groups, entering and leaving Viet Nam should shed considerable light on the incidence of subclinical infections. Related to the epidemiological study, it will be necessary to determine whether a positive serological test (the presence of antibodies) is an indicator of chronic infection or of a previous subclinical infection.

It is recognized that melioidosis has not been a major public health problem but, for the few individuals exhibiting clinical symptoms, it is a serious disease. Because of the low incidence of melioidosis, vaccines probably are not a practical solution. However, attempts to produce an effective vaccine should be continued because information gained in such studies might be of value in treatment, particularly of chronic cases.

Emphasis in future studies should be on therapy because the mortality among those exhibiting clinical symptoms is still high. Perhaps a combination of chemotherapy and antitoxin should be considered.

REFERENCES

1. Dannenberg, Arthur M., Jr. and Scott, Eva M. 1958. Melioidosis: Pathogenesis and Immunity in Mice and Hamsters. I. Studies with Virulent Strains of *Malleomyces pseudomallei*. J. Exptl. Med., **107**:153-166.
2. Nigg, Clara, Ruch, John, Scott, Eva and Noble, Kathryn. 1956. Enhancement of Virulence of *Malleomyces pseudomallei*. J. Bacteriol., **71**:530-541.
3. Heckley, Robert J. and Nigg, Clara. 1958. Toxins of *Pseudomonas pseudomallei*. II. Characterization. J. Bacteriol., **76**:427-436.

Ocean Circulation Models

The January 1970 issue of SCIENTIFIC AMERICAN features on the cover a "Model of Oceanic Circulation" by Dr. D. James Baker, Jr., Harvard University. Dr. Baker's research on oceanic circulation models is supported by ONR. Dr. Baker's excellent article discusses the philosophy behind making ocean models, and their limitations, as well as how they can substantially aid in the analysis of the ocean's response to forces by isolating the major features of the physics of ocean circulation.

The results obtained with a small, homogeneous, rotating model (that takes into account the variation of the Coriolis parameter with latitude) are described and illustrated with numerous photographs.

XUM

Legal Protection of Computer Programs

Frank G. Nieman
Office of Naval Research
London

"Is this reality or fantasy?" might very well be the question. A multi-billion dollar industry, relatively young but continually growing under partial cover of the legal statutory protection of the patent and copyright laws, holding a conference to decide what, if any, legal protection is desirable for the product of their collective mind, the computer software.

The British Computer Society held for the first time, a conference in Brighton on the legal protection of computer programs. In spite of the unusually high conference fee of $66.00, when compared to other conferences here in the UK, it was attended by over 240 persons interested in the computer hardware and software industry, including management personnel and programmers of the computer user, lawyers, patent agents, and academicians. The conference set an impossible task for itself. It tried to examine the present legal protection for computer programs in the UK, Europe and the US in an acceptable and understandable manner for an audience of such diverse background, interests and training. It also tried to predict the future developments in this complex area.

One of the factors which sparked interest in this question of legal protection for computer programs is the change in some of IBM's practices whereby the computer program is priced separately from the computer. This change highlighted the commercial value of the computer software. At times the discussion at the conference sounded rather two-sided, IBM vs the remainder of the computer world. Perhaps a look at the origin of the attendees may be relevant to this observation. Of approximately 240 attendees, IBM had twenty-nine delegates from seven different countries.

There was a generally accepted starting point—some legal protection is necessary for computer programs—but a definition of what a computer program includes was never reached. Some believe the goodwill of a software corporation is within the definition, while others would limit its applicability to the more tangible and more closely coupled information directly used to control the computer.

A good number of those present, including IBM, are content with the protection that is now available. Here is a very brief outline of that protection. There is no protection *per se* for computer programs in the US, UK or France. There is patent protection available in both the UK and the US, when the computer program is claimed with the computer. The most recent US decision, 14 August 1969, by the Court of Customs and Patent Appeals, in re Prater and Wei, 162 USPQ 541, held patentable a broad apparatus claim that covered the use of the program in both analog and digital computers but failed to determine whether a process claim covering the method of performing the program was a proper claim under the statute. It was unnecessary to decide this latter point since the claim was written in a manner that could include human-mental calculations, and thus the claim did not limit itself to the machine-implemented process. The claim failed to particularly point out and distinctly claim the invention and was therefore unpatentable.

XUM

The most recent UK Patent Office decision is Slee and Harris's Application decided in 1965 (1966 Reports of Patent, Design and Trade Mark Cases 194) which refused to allow a claim to a method of operation by a computer program, but did allow a claim to a computer modified to operate according to a program. The UK Patent Office did not object to a claim to a machine modified to operate according to a program because a "serious and relevant argument" was made that the program is like a cam shaped according to certain formulae to control the machine in a certain way. Another UK decision may be coming out relating to patentability of computer programs, but further information is not available at this time. Additionally, the Banks Committee, which is studying the entire UK Patent Act, is taking evidence on patent protection for computer programs. The Banks Committee report was originally scheduled to come out near the end of 1969.

Protection under the copyright laws both in the UK and the US is now possible, but the extent or value of the protection has not been tested in the courts. The difficulty is that the law does not literally read on computer programs as they appear in some of their various forms such as tape, discs, drums, cores, punched cards and paper. Relatively few computer programs have been registered in the US. Registration is not required under the UK copyright laws, and thus there is no comparison, except that no suit for infringement of copyright in computer programs has been reported in either country.

Patent law and copyright law provide the statutory protection. Other non-statutory protection now exists by way of contracts either with employees or users of computer programs. The law of trade secret also is another form of protection, but the problem in keeping the computer program secret. Other minor remedies appear in criminal law for theft and in the law of torts for conversion.

Two legislators, one MP from the House of Commons and a Lord from the House of Lords, advised the use of caution and careful consideration of the problem, remedy and protection needed before approaching Parliament to seek a new form of legal protection.

As a conclusion to the conference it appeared the majority of the delegates favored copyright protection over patent protection, if there were to be statutory protection at all, although a significant number appeared to think present protection already was adequate. The reason for the choice of copyright law protection over patent protection appeared to reside in the fact that obtaining a copyright entails relatively no expense and the number of amendments needed to afford protection under the UK copyright act are minimal. The difficulty with patent protection is the lengthy and costly procedures necessary to obtain patent protection. The general feeling that the patent offices in the US and UK are opposed to the extension of patent protection to computer programs also contributed to the choice of copyright protection in preference to patent protection. The differences between the protection afforded by a patent or a copyright is that patent protection grants the right to prohibit the making, using, and selling of the computer program. Copyright, on the other hand, protects only against copying.

Virtually no time or discussion was devoted to an analysis of the effectiveness or the adequacy of the protection afforded and the problems of enforcement of the rights protected under the copyright and patent laws. Had all relevant

XUM

factors been carefully considered, there very well could have been another consensus. Provision is being made for further consideration of this topic because the British Computer Society hopes to have further conferences on this subject of legal protection for computer programs.

For the present, the advice coming from the panel of experts appears to be to protect what you can by patents, copyright the computer programs, and have well-written contracts with employees and users. The question was raised regarding the rights of the user of computer software, but this will have to wait for an answer, or perhaps the user has no rights in the computer program or its further developments once the contract is signed with the supplier of the software? This question was beyond the scope of this conference.

What the future development in the legal protection of computer programs is going to be appears at this time to be open to anybody's guess. Certainly, this conference was not the birth of any new legal protection. Whether the conference aided the conception of additional legal protection for the software industry only time will tell.

Casting of Structural Ceramics

Techniques for measuring changes in the properties and structure of molten oxides at temperatures approaching 3000°C have been developed at Battelle-Northwest under ONR sponsorship. Fundamental property data of oxides at high temperatures, which were not previously available, are now being obtained.

The materials work described below is fundamental to improved and controlled processing of high temperature ceramics and glasses in such operations as melting and casting, and is applicable to improvement of behavior of monolithic ceramic components needed by the Navy as load-bearing structures.

The procedures involve sealing oxide samples in refractory metal capsules and employing radiographic techniques which permit the study of materials with a high-vapor pressure near the melting point, without a change in composition. Video tape and/or X-ray film enables the scientists to study surface tension, thermal expansion, volume change on melting, density, viscosity, and compressibility. To date, this work has been done on oxides of aluminum, chromium, samarium and uranium.

By knowing the properties and structures of the oxides during melting, manufacturers may also be able to improve their crystal growing processes. This new knowledge of the properties and structures of these ceramics may enable scientists to learn which parameters have the greatest influence on the growth of oxide single-crystal filaments used as reinforcement in high strength materials.

In other tests, aluminum oxide has been sealed in tungsten capsules by electron beam welding in vacuum, and then heated as high as 2800°C. The thermal expansion of the solid and the molten oxide, the volume change on melting, and the surface tension of the molten aluminum oxide were measured.

This group has also modified a high-temperature furnace to study the viscosity of liquid oxides by an oscillating cup viscometer technique. The oscillation of the cup containing the liquid is recorded on video tape. The tape can be played back in stop action to obtain the decrease in amplitude of oscillation due to the viscous motion of the liquid. Viscosities are calculated from the damping and the period of oscillation.

Ultrasonics are being used to study molten oxides and to determine the adiabatic compressibility and ultrasonic velocity. As the temperature is increased, changes in the sound velocity are found which indicate that a change in properties and structure of the liquid oxide occurs.

XUM

Research Notes

Application of ONR Code 437 Task to Physics Program

ONR Code 437 has been sponsoring advanced man-machine on-line computing techniques at the University of California, Santa Barbara (UCSB) under Glenn Culler. The results of this task have been of considerable assistance to ONR Code 421 Physics Task which is also at the University. The 437 task has enabled Burton Fried and his co-workers to build up computer simulations of plasma phenomena which have the characteristics of an actual experiment. The UCSB on-line computer terminal system has been adopted as the standard means of carrying out the simulation. The Atomic Energy Commission has shown sufficient interest in the results so far to install terminals at Princeton and Oak Ridge Laboratories and to fund University of California at Los Angeles to convert the UCSB system to their own IBM 360/91 computer. Its advantages are its similarity to desk calculator operation, its software capability for array manipulation and graphical display, and the direct mode of interaction during calculation. According to Fried, many computer plasma simulations have involved large numbers of particles, batch processing, and consequently wasted time in following unimportant motions. The interactive approach permits the scientist to watch the "interesting" particles and to develop a theory of their motion in real-time.

One problem involved trapping of particles in an electrostatic wave. The particles followed in detail were those with velocities near resonance with the wave velocity; the rest of the particles in the distribution function were treated by linearized continuum theory. The interactive mode of the UCSB system enabled Fried to formulate correctly the boundary effects which originated from the artificial separation of the discrete particles whose trajectories were treated separately from the remainder, whose motions were followed with a Lagrangian formulation. The main results to date have been to establish two types of wave behavior: one in which damping abruptly terminates the waves and one in which steady oscillation of the wave amplitude is reached.

Fried had worked closely with Culler in designing the on-line computer console and the software capabilities. As applied to plasma physics problems, the system seems to have many advantages and considerable flexibility.

Ice Island Rotation

Listening arrays designed to measure the direction of hydroacoustic sources are affected by the rotational dynamics of the platforms on which the arrays are located. A research program using a passive listening array is located on Fletcher's Ice Island T-3. Observations at Ice Island T-3 show that the station has rotated through large angles during summer months. For example, during the summer of 1962 T-3 rotated clockwise 2700 degrees. Another property of the ice island is that often it becomes locked into the pack ice with an orientation of the intermediate principal axis of inertia approximately north-south. Dr. K. L. Hunkins, Lamont Doherty Geological Observatory has had some success in explaining this rotational behavior by applying the rigid body equations of motion to the ice island taking into account the earth's rotation. This approach seems justified when the ice island is not rigidly locked into the ice pack. Moderate success has been obtained in predicting the angular displacements as a function of time, and shows that the intermediate axis of inertia in a north-south direction is a position of stable equilibrium. The principal unknown in the computations is the amount of pack ice attached to the ice island. Visual observations and serial photographs have been used to provide estimates of the shape and extent of the attached pack.

XUM

Deep Sea Drilling Project

The research vessel *Argo* of the University of California, San Diego's Scripps Institution of Oceanography arrived back in San Diego, Thursday, February 19, and berthed at Scripps' Nimitz Marine Facility after completing successful geological and geophysical surveys of ten additional Pacific Ocean sea-floor sites selected for drilling in the Deep Sea Drilling Project (DSDP).

Last year, in Expedition Scan, scientists aboard the *Argo* selected 23 sites for DSDP operations between here and Japan. The second part of Expedition Scan, which began at Papeete, Tahiti, last mid-October, logged 21,098 miles between Tahiti and Balboa, Canal Zone; from Balboa westward and thence to Acapulco, Mexico; and from Acapulco to San Diego. The site-selection work involved investigating sediments and geological formations into which the *Glomar Challenger* drilled during her Pacific Ocean operations in 1969. The *Glomar Challenger* completed that work recently and left Galveston, Texas, for Miami, Florida, on the first leg of an extended drilling program that will eventually take the ship into the Atlantic, Indian, and Pacific Oceans, and the Mediterranean Sea.

Argo's site-selection work was supported by the National Science Foundation (NSF) and the Office of Naval Research (ONR). The DSDP, which is part of NSF's National Ocean Sediment Coring Program, is conducted under contract by Scripps Institution; JOIDES serves in an advisory capacity to the DSDP.

Dr. Russel R. Raitt, professor of geophysics; and Drs. John G. Sclater and Gerald B. Morris, both assistant research geophysicists, served as chief scientists between Tahiti and San Diego. Capt. John W. Bonham was master of the *Argo* during the expedition.

Using reflection profiling, echo-sounding, and a magnetometer, scientists aboard *Argo* surveyed two drilling sites northeast of Tahiti within two weeks of the ship's departure from Papeete on October 18. The ship then stopped briefly at Pitcairn Island to disembark four U.S. Air Force personnel who had been conducting a geodetic survey and take on their replacements.

As the *Argo* was about to depart Pitcairn, Dr. Raitt suffered a broken leg and Dr. Morris replaced him as chief scientist for the remainder of Legs 8 and 9 of the expedition.

The *Argo* then headed southwest of Mangareva a distance of 600 miles to survey a possible active undersea volcano that rises about 13,000 feet from the seafloor to within 125 feet of the surface. This volcano had been discovered several months earlier by Dr. Rockne Johnson of the University of Hawaii. He had noticed that seismic disturbances or rumblings appeared to originate in this area and had predicted the volcano's existence from seaquake records.

Rock samples were dredged from the top of the volcano and water samples taken from its top and sides, but listening devices lowered into the water failed to detect any extraordinary sounds.

No drilling sites were discovered enroute back to Papeete that met DSDP drilling requirements and Leg 8 ended at Papeete on November 12.

On Leg 9, between Papeete and Balboa, the scientists surveyed six drilling sites in the thick sediment lying along the equator. It was during this period that extensive refraction work was conducted that normally requires at least three ships.

The scientists and technicians continued using a technique Scripps developed earlier, in which only one vessel is needed. In this, the *Argo* dropped explosive charges; moored floating buoys as much as 50 miles away would act as listening stations. The buoys were equipped with underwater listening devices and radio transmitters that sent the received signals back to the *Argo*.

Because of the line-of-sight limitations imposed by ship-mounted antennas at the very high frequency used by the buoy, the radio transmitter was attached to a line to a balloon some 600 feet above each buoy to extend the buoy's range. Thirteen combination balloon-buoy packages were used during Leg 9.

XUM

Numerous problems did arise with such a complicated system. The balloons occasionally fell victim to intense squalls, sharks bit through the mooring line setting the buoy adrift, and fish actually ate large parts of the styrofoam floats. In spite of such difficulties, the system usually worked.

During Leg 10, between Balboa and Acapulco, two DSDP site surveys were made over the East Pacific Rise, off South America. Many heat-flow measurements were taken on this run. Twenty geochemical stations were occupied and hundreds of seawater samples taken to measure helium, helium-3, argon, nitrogen, silica, total carbon dioxide, radium, and radon concentration and the isotopic composition of dissolved oxygen and carbon.

Underwater Acoustics

The program in underwater acoustics, carried on by Dr. John C. Steinberg and associates at the University of Miami, under ONR sponsorship is concerned with understanding relationships between variations in the amplitude and phase of transmitted sound waves and variations in the environment. The environment includes the water column and bottom, the atmosphere, and the air-sea interface. If the basic processes involved in the relationships can be determined, estimating ocean weather and sonar conditions from atmospheric observations becomes a possibility.

In the program, continuous wave signals of 420 Hertz are transmitted across the Straits of Florida on a continuous basis from a fixed projector off Miami, to fixed hydrophones located at distances of 3, 7, 42, and 43 miles from the projector. By phase coherent detection, both the amplitude and the phase of the sound received at the hydrophones are obtained as functions of time. The quantities are referenced, respectively, to the amplitude and phase of the initial wave. Since the system is fixed, observed variations are ascribable to environmental changes. Temperatures are measured at five depths in a 260-meter water column near the 3-mile hydrophone off Miami and between the 42- and 43-mile hydrophones off Bimini, Bahamas. The potential difference between electrodes located near the 3- and 7-mile hydrophones is also continuously measured. Underwater instrumentation at Miami and Bimini are cable connected, respectively, to receiving equipment in acoustic laboratories at Virginia Key and at Bimini.

During the past year, the acoustic phase and amplitude measurements were extended from a five-month to an eighteen-month continuous period. Temperature measurements off Miami were extended from a four-month to a seven-month period. The 7-mile hydrophone, the 260-meter thermistor strings, and the 3- and 7-mile electrodes were installed this year, and the program is now embarked on a one-year measurement interval.

The measured quantities are represented as functions of time and as spectra of the time functions. Data on wind velocity, barometric pressure, and air temperature obtained from the Weather Bureau are similarly represented. Progress has been made with a statistical model which shows the relative significance of variations in the environmental quantities to the acoustic amplitude and phase variations. Work is also proceeding on an acoustic propagation model incorporating the time-varying features of the sound speed versus depth profile along the sound path.

As noted in previous reports, highly phase coherent transmission is observed over intervals up to a few minutes duration (phase varivations are negligible). Over longer intervals, significant phase variations occur which correspond much more directly with environmental changes than do variations in amplitude.

The short-period phase variations include periodicities of a few seconds and a few minutes associated, respectively, with surface waves and interval waves. Their magnitudes (double amplitude) range from 20 to 90 degrees of phase shift.

Long-period variations show periodicities associated with the tides (twelve and twenty-four hours) and with weather changes and the passage of cold fronts (two to fifteen days).

XUM

Periodicities in the latter range also appear in the variations of wind velocity, barometric pressure, and air temperature for the same time interval. There are indications of seasonal changes, but measurements have not been made over sufficiently long intervals to determine periodicities. The tidal variations ranged from two to twelve phase cycles of 360 degrees each. Weather periodicities showed magnitudes of ten to fifty phase cycles. Magnitude of the variations tended to increase with increase of period.

With the extension, for the first time, of phase measurements over an interval of a year, a strong twenty-seven-day period appeared in the record. It is believed to be associated with the period of lunar declination (27.3 days) and was strongest in late March. Its magnitude was some five times greater than that of the daily period associated with the tide.

Preliminary considerations suggest that variations in the temperature-depth structure along the sound path arise from changes in the geostrophic balance of the horizontal Coriolis and horizontal pressure forces as variations of current transport across the sound path occur. Variations of acoustic phase result from the temperature changes because of the east-west asymmetry in the vertical and horizontal temperature gradients. Changes of transport result from variations in gravitational and atmospheric forces.

Comparisons of variations in the potential difference between the 3- and 7-mile electrodes (transport variations) with the phase variations at the 7-mile hydrophone show close correspondence in the tidal range of periodicities. Moreover, perturbations associated with changes of wind speed appear in both the curves of transport and phase versus time. These observations extended over an interval of only a few weeks which is not long enough to indicate longer period changes.

If phase variations are indicative of changes in transport, monthly variations would be expected to exceed daily variations by substantial factors. The increase in magnitude with increase in period points up the desirability of measurements on a continuous basis over time intervals some five to ten times longer than the periodicities of interest. There is also evidence of an east-west shift in the axis of transport with lunar declination. The shift will appear in the phase variations because of the east-west temperature asymmetry noted earlier and because of the east-west variation in depth. Continued measurements and study are planned in order to clarify these relationships.

State of the Art of Immunochemistry

The Biochemistry Program Manager (code 442) co-sponsored a meeting of eminent immunochemists, loosely knit as a "non-society" which meets once a year on the West coast. About 300 scientists, including several current and past ONR contractors recently met in Coronado, California to hear detailed accounts of what is considered to be the most significant work in the field. The size of the group, its composition and the format favor really critical and helpful discussion which is a source of understanding and inspiration for the leaders in the field, and for the program planning in Code 442 as well.

It was particularly evident this year that a phase in the science of immunochemistry has just been completed, and that a new phase is beginning. Perhaps a decade has been devoted to anlaysis and description of the molecular structure and physical properties of the compounds which are mustered by the body in response to challenge by germs and foreign biological materials. Attention is now turning to the physiological and pathological implications of the knowledge that has been gained, which is to say, to the solution of problems of practical value in immunization and in the understanding and management of diseases which are due to undesirable consequences of the immune response. Research in this field has been suffering from a lack of academic interest. There is every reason to think that the next two to five years will be a time of payoff in terms of revised methods of treatment, improved immunization procedures and new medical "miracles" of direct and important value to the naval medical practitioner and surgeon.

XUM

Surface Slicks

Concentrations of up to 13 parts per billion of chlorinated pesticides were measured in natural surface slicks in Biscayne Bay, Florida, by Dr. Eugene F. Corcoran and Dr. Douglas B. Seba of the University of Miami Rosenstiel School of Marine and Atmospheric Sciences. At the same time, the researchers found that water surrounding the slicks generally contained less than 1 part per trillion—or less than 1/10,000—of the pesticides found in the slicks.

"Natural surface slicks may explain the occurrence of pesticide residues in penguins in the Antarctic, or the disappearance of pelicans from nearly all of the U.S. seacoasts," said Dr. Corcoran. "In Biscayne Bay, for example, we have observed gulls and pelicans diving into surface waters to feed on the dense schools of small fish that feed on plankton concentrated in the slicks. Since these sea birds eat many times their weight in fish, they eventually have more pesticide concentrated in their tissues than the fish did.

Surface slicks are natural oceanographic phenomena which appear as calm streaks or patches on the otherwise ripple surface of lakes, coastal waters, and open ocean areas. In aerial surveys of Biscayne Bay, slicks varied from a few meters to over 100 meters in width and up to several miles in length. During the summer of 1968, aerial photographs revealed that about 10 percent of the bay was covered with these slicks.

The slicks may be wind-induced or may occur where two water masses converge. The converging water caused compaction of the film of dissolved organic and inorganic molecules normally found on the surface of biologically productive waters, thereby providing a tremendous supply of nutrients. Some of the nutrients are used directly by phytoplankton (microscopic floating plants); others combine into small particles and are used by filter-feeding animals.

The cycling of pesticides depends not only on food web interactions, but on the interaction between the atmosphere, water, silt, and bottom deposits. In a study with Dr. Joseph M. Prospero, Dr. Seba found that atmospheric dust collected at Barbados, West Indies, after it had crossed 4,000 miles of open ocean, contained appreciable amounts of several chlorinated pesticides. These pesticides were similar to those found in Biscayne Bay surface slicks, and indicate that the Atlantic tropical tradewinds are responsible for transporting significant quantities of pesticides from the continents to the open-ocean ecosystem. The researchers also found pesticides in the rainwater of tropical hurricanes.

This research was supported in part by the Federal Water Pollution Control Administration, the National Science Foundation, and the Office of Naval Research.

Dr. Mina Rees Honored

Top news in the scientific community in December was the election of Dr. Mina S. Rees to the Presidency of the American Association for the Advancement of Science (AAAS) for the year 1971. Currently Dean of the Graduate Division of the City University of New York, Dr. Rees is widely known for her service on many scientific and educational committees and panels, and is well remembered for her six years at ONR. One of the original Scientific Branch Heads, she helped to develop the unique character of ONR activity in the position and later as the Director of the Mathematical Sciences Division from 1947 to her departure in 1953. She was largely responsible for the establishment of a Computer Science Program in ONR, and, in particular, brought about the WHIRLWIND Project at MIT, a pioneer of the large-scale, high-speed computing systems with parallel access memory and multiple inputs, which, with its near real-time capability, made it useful as the basis for the SAGE air defense system.

XUM

Underwater Low-Cost Housing

A. B. Focke
Office of Naval Research
London

A group of undergraduate and graduate students of the University of London carried out a set of experiments during the summer with underwater habitats. The project was coordinated by a graduate student from Imperial College, Mr. Brain Ray. The other members of the group consisted of six undergraduate students from Imperial College headed by B. Newman, a group of four undergraduate students from Enfield College under the leadership of David Baume, and two medical students from the Westminster Medical School. The students designed and built two small underwater houses whose dimensions were about 5 ft × 9 ft × 7 ft high. The first house, SDM/1, consisted of a steel frame covered with a rubberized fabric envelope (ESN 23-3, 1969). This was moored at a depth of 30 ft in 70 ft of water and filled with air pumped from the surface. Once filled, all contact with the surface by cable or hose was disconnected. Oxygen supply and carbon dioxide clean-up was provided by a 24-hour life support package which was changed daily. SDM/1 was damaged beyond repair by a sudden storm on August 17, during which the relative motion of the fabric and the steel frame caused ripping of the fabric and consequent loss of the whole structure. Four days later SDM/2 was launched and moored at about 20 ft in 30 ft of water. This house consisted simply of a 5 ft × 9 ft oval steel pipe frame to which was fastened a rubberized fabric balloon which, then inflated, formed a bubble approximately 5 ft × 9 ft × 7 ft high. A wooden floor also was supported by the steel frame. The change in depth provided the possibility of flooding and abandonment at short notice without damage to the structure and without incurring any problems of decompression for the swimmers if they had to leave in a hurry. Both of these house structures could be carried by about six men and placed on the top of a station wagon for overland portability. Minimal electric power was provided by means of a 100-W, 12-V fuel cell made by Electric Power Storage Company, Ltd., and separately moored at 30-ft depth. Voice communication between divers and personnel on the surface was maintained through the use of the underwater communication system developed by Ray. Some members of the team spent as much as four days under the surface. The only medical problem noticed was some difficulty with fungus growth in some of the participants' ears.

During their stay under water, the students made studies of the ability of a diver to determine the direction from which sounds came to them; the characteristics of communication by means of a communication system developed by Ray, which used audio-frequency currents transmitted into the water by separated electrodes; the operation characteristics of the fuel cell; the performance of the life support system; as well as making observations on their own ability to explore the sea floor in the vicinity of their habitat. The students were enthusiastic over the success of their project and have submitted at least one report on it to *Nature*.

XUM

On the Naval Research Reserve

NRRC 9-10

Naval Reserve Research Company 9-10, Evanston, Illinois, has been presented both Ninth Naval District and National First Place General Excellence Awards for the 1969 fiscal year.

In a recent ceremony at the Great Lakes Officers' Club, Rear Admiral Henry A. Renken, Commandant of the Ninth Naval District, and Rear Admiral Thomas P. Owen, Chief of Naval Research, presented the awards in a special dual event.

RADM Owen presented the national award to Commander Benedict J. Jaskoski, of Chicago, who was commanding officer of the company during the competitive year. RADM Renken presented the district award to Lieutenant Jacob D. Dumelle, of Oak Park, the new commanding officer.

The 21-member company was judged for these awards on inspection grades, training grades, Ready Reserve Status and drill attendance.

Rear Admiral Thomas P. Owen, Chief of Naval Research, presents the Naval Reserve Research General Excellence Award to Commander Benedict J. Jaskoski, former commanding officer, NRRC 9-10, Evanston, Illinois.

XUM

Promotion Selections

There were 132 Naval Reserve line officers selected for promotion to Captain by the Fiscal Year 1970 Reserve Selection Board. Three were members of the Research Reserve Program.

	NRRC
Bohan, Walter A.	9-10
Davis, Charles F.	1-1
Housiaux, John E.	9-4

Two of these officers were from the new field.

NRRC 6-9

Strong ties exist between Naval Reserve Research Company 6-9, Athens, Georgia and the University of Georgia, which is the oldest chartered state university in the nation. The company has a high quality training program primarily because of the cooperation of University faculty and staff.

Programs combining general subject background and recent research developments were based on studies of the visually handicapped, marine resources, the psychology of student revolt, university personnel recruitment, development of management systems, university auxiliary enterprises, and computerization of student records. Each quarter attention is given to naval subjects with at least one drill devoted to leadership. The majority of training is conducted by University personnel and other persons in research.

LCDR T. E. Molitor, USNR, Named Minnesota Teacher of the Year

LCDR Theodore E. Molitor, USNR, a member of the Naval Reserve Research Company 9-6, Minneapolis, Minnesota was named "Teacher of the Year" in a competition sponsored by the Minnesota Education Association and the Minnesota State Fair. The competition included every school teacher in Minnesota.

LCDR Molitor is a chemistry teacher in the Alexander Ramsey Senior High School of Roseville, St. Paul's largest contiguous suburb and is a research consultant for the Roseville school system. He is the author of several articles written for scientific journals and is on the board of directors for the Minnesota Academy of Science.

LCDR Molitor also received recognition for this Naval Reserve activities last year. While in command of NRRC 9-6, his unit won the Research Reserve Award for General Excellence, the national competition which included 97 Research Reserve Companies.

U. S. GOVERNMENT PRINTING OFFICE : 1970 O - 379-054

XUM

M.I.T. Vibrating String Surface-Ship Gravimeter

The increasing sophistication of inertial navigation system in both manned and unmanned vehicles has led to a growing need for worldwide geodetic data. A significant portion of these geodetic requirements involves the acquisition of marine gravity data over the world's oceans. Because of this and because of the state of instrumentation in marine gravimetry, ONR, over the past few years, has provided considerable support for the development of new surface-ship gravimetric instrumentation. One of these developments is now completed and field tests and evaluation of the new system have been carried out successfully over the past two years. The new gravity sensor consists of a double-vibrating-string accelerometer which was initially developed commercially by American Bosch-Arma for use in the Air Force missile program. The thermal oven and electronics associated with the accelerometer for its use as a gravity sensor at sea were developed under the direction of Dr. Charles G. Wing at MIT. The system as developed is smaller, less complex, and substantially less expensive than existing gravimeters and is expected to be more reliable and accurate.

As the potential success of this development became apparent, a number of the vibrating string accelerometers, which had been declared excess to Air Force needs, were acquired. These accelerometers, numbering about 250 are being placed in inventory at MIT and will be tested by Dr. Wing to determine their thermal sensitivity and drift characteristics. It is estimated that about 1 out of 4 of them will be found to be suitable for marine gravimetry applications.

As a direct result of this ONR supported development program, the ARMA Corp. has gone ahead with the development of a commercial version of this sea-gravity system.

The system and results of field tests have recently been described in the following reports: Wing, C. G., The M.I.T. Vibrating String Surface-Ship Gravimeter, Tech. Rpt. No. DSR 75162-1 (Contract Nonr 1814(74) Task No. NR 083-157), 106 pp., Sept. 1969. Wing, C. G., M.I.T. Vibrating String Surface-Ship Gravimeter, J. Geophys. Res., 74(25), 5882, 1969.

NAVAL RESEARCH REVIEWS publishes highlights of research conducted by Navy laboratories and contractors and describes important naval experimental facilities. Manuscripts submitted for publication, correspondence concerning prospective articles, and changes of address, should be directed to Code 109, Office of Naval Research, Washington, D.C., 20360. Requests for subscriptions should be directed to the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402. Subscription price: $1.75 per year in the U.S. and Canada; $2.25 per year, foreign; $0.20 per individual copy. The issuance of this periodical approved in accordance with Dept. of the Navy publications and printing regulations.

Editor: WILLIAM J. LESCURE

Associate Editors:

T. B. DOWD, ONR BOSTON
L. A. WHITE, ONR CHICAGO
I. ROWE, ONR NEW YORK
E. GLOYE, ONR PASADENA
P. MILLER, ONR SAN FRANCISCO
J. DE LAUNAY, NAVAL RESEARCH LABORATORY

NAVSO P-510

XUM

IN THIS ISSUE

VOL. XXIII, NO. 3

Amorphous Semiconductors ..... ROBERT G. MORRIS 1

ONR is sponsoring research in this field to improve the communications, surveillance and navigation of the fleet.

Melioidosis ..... ROBERT J. HECKLY 8

This fatal disease of South East Asia is better understood as a result of ONR research.

Research Notes 21

On the Naval Research Reserve 27

Computer programs placed helter-skelter on the page. Should they be legally protected? See Page 18.

DEPARTMENT OF THE NAVY
OFFICE OF NAVAL RESEARCH
WASHINGTON, D.C. 20360

OFFICIAL BUSINESS

POSTAGE AND FEES PAID
DEPARTMENT OF THE NAVY